

**MEASURING HUMAN PERFORMANCE ON NASA'S
MICROGRAVITY AIRCRAFT**

**Randy B. Morris and Mihriban Whitmore
Lockheed Engineering and Sciences Co.
2400 NASA Rd. 1, C95
Houston, TX 77058**

Abstract

Measuring human performance in a microgravity environment will aid in identifying the design requirements, human capabilities, safety, and productivity of future astronauts. The preliminary understanding of the microgravity effects on human performance can be achieved through evaluations conducted onboard NASA's KC-135 aircraft. These evaluations can be performed in relation to hardware performance, human - hardware interface, and hardware integration. Measuring human performance in the KC-135 simulated environment will contribute to the efforts of optimizing the human - machine interfaces for future and existing space vehicles. However, there are limitations, such as limited number of qualified subjects, unexpected hardware problems and miscellaneous plane movements which must be taken into consideration. Examples for these evaluations, the results, and their implications are discussed in the paper.

INTRODUCTION

In order to design environments and develop countermeasures as well as support systems that protect and enhance human capabilities, safety, health, and the productivity of future astronauts, we need a thorough understanding of the microgravity environment. By gaining this understanding, the probability of achieving greater mission successes is enhanced. One way of gaining this preliminary microgravity information is through the use of NASA's KC-135 aircraft, which simulates this environment. The KC-135 aircraft is ideally suited for short duration tasks. These tasks can evolve gross and fine motor activities and validating technology concepts. Some of the concerns

with the various users are their anthropometric, physical, and physiological capabilities. A human factors goal is to provide designs/ interfaces for living and working in a microgravity environment and flight hardware in order to achieve optimal human performance, while providing safe human - machine interfaces. ¹

APPROACH

In order to achieve the best human - machine interface, human performance can be measured on the ground, KC-135, and the shuttle. These evaluations (KC-135) have been performed in relation to hardware performance, human - hardware interfaces, and hardware integration. One type of evaluation is to evaluate the hardware's

performance in microgravity conditions. These evaluations look at the equipments functionality and maintainability. Two examples of this type of evaluation are the video tape recorder (VTR) and Macintosh Powerbook 170 evaluations. This type of an evaluation is increasing in importance as the recent trend is to use commercially off the shelf products. While these products work quite well in the presence of gravity, in its absence, unforeseen problems can arise. Therefore, it is advantageous to test an off the shelf product for the microgravity environment and make modifications, if necessary, instead of designing a completely new product for microgravity use. Some examples of these problems include a trackball that had too much play in the ball (ball mechanism floated), and unexpected loss of camcorder battery power.

The VTR evaluation looked at the machine's servo circuits characteristics by way of the Horizontal Sync Jitter and Signal-to-Noise Ratio tests, as well as the man/ machine interface characteristics such as tape ejection and insertion, activating play, search (in both directions), fast forward and reverse (see Figure 1). All of the VTR's mechanical and operational tests were successful with no difficulties encountered. The only recommendation was to add a finger restraint to allow the operator to stabilize their hand for button activation.² While the Powerbook evaluation looked at the text/ graphics readability, display angle adjustability, select button activation pressure and location, keyboard location and the keys' pressure,

restraint requirement, and size, shape, and location of the trackball. In general, the Powerbook computer worked well on the KC-135.³

Human hardware - interface involves the location, type, size, and ease of use of displays and controls.



Figure 1 - Subject Evaluating VTR

An example of this type of evaluation is the Cursor Control Device Evaluation (see Figure 2). The objective of this experiment was to aid in determining the best cursor control device design for use in microgravity. An optical mouse, trackball, mouse pen, and thumb ball are some of the cursor control devices that were tested. The experiment consisted of performing a text editing task which required pointing, dragging and clicking. Dragging time, pointing time and percentage of correct responses have been analyzed as

performance measures. Results of these evaluations showed mechanical deficiencies and performance differences among the devices. The ones which exhibited the best performance were selected for evaluations onboard the Shuttle.⁴



Figure 2 - Subject Evaluating Cursor Control Device

The third type of evaluation is the integration of the hardware into the overall system (e.g. is the proposed location for the equipment a feasible location). The workstation evaluations fall into this category (see Figure 3). The objective of this study was to evaluate the physical dimensions and layout of the workstation components. The workstation components consisted of the keyboard desk, translational hand controller, rotational hand controller, monitors, control panels and mobility aids while using

different foot restraint systems. The entire evaluation was video taped for post flight computer simulation modeling. The results from the KC-135 flight showed that the workstation keyboard desk height and restraint systems concepts, as well as the location of the hand controllers would be critical for accommodating the required range of users (147.32 cm to 193.04 cm) in the microgravity neutral body position.^{5,6}

The microgravity testing is an important part of hardware development as a tool to increase human performance because it allows the investigators to see the effects of weightlessness on the human - machine interface. It also gives you a chance to make some design refinements if any are necessary before it actually goes into space. This allows the investigators to save time and some potential problems.

Pre-flight Preparations

There are several preflight activities which must be completed no later than six weeks prior to the flight. One of these are the preparation of your hardware to ensure that it meets the qualifications for the KC-135. The equipment must be able to fit in the aircraft and be able to withstand the appropriate flight loads in the takeoff and landing configuration. Subject selection is another very key issue since there is a limited number of qualified subjects. The other two important issues are the selection of the performance measures that you want to measure and the design of your test protocol.



Figure 3 - Subject Evaluating Workstation

Baseline data was collected on the ground prior to the flight. This gives you performance measures in a normal ground (one g) environment to compare to the participants microgravity (zero g) performance measures. This baseline data collection also serves as a dry run to your actual experiment by familiarizing the participants with the hardware and what exactly they will be doing during this evaluation, as well as allowing you a chance to modify the test protocol if necessary.

Flight

NASA's KC-135 aircraft simulates a shirt sleeve space flight environment. It flies in a parabolic flight pattern that produces a

microgravity period ranging between 20 and 27 seconds with an average of 23 seconds. The microgravity period is preceded by a two-g pull up and two-g pull out. The duration of these flights is approximately two hours with the total microgravity time being between fifteen and eighteen minutes.

During the KC-135 flights the human performance measures can either be objective or subjective. As a minimum, subjective data is collected during all of the evaluations. If the nature of the experiment allows, objective data is also collected. The subjective data is collected through questionnaires and audio comments that the

participants have made during the evaluations. While some examples of the objective measures are task completion time and percent error, frequency of use, anthropometric/physiological measurements. These are collected through video recording or software.

Post Flight

After the flights, the participants are given a follow-up briefing and (if necessary) more data will be collected for analysis and comparison to the flight and baseline data that was collected previously.

RESULTS

The advantages of performing experiments onboard the KC-135 are that they are cost effective and, if applicable, design refinements can improve the interface and thereby improve human performance. A good example of this was during the cursor control device evaluations onboard the KC-135, where there was a mechanical deficiency with the trackball. This deficiency was that the ball floated due to too much "play" in the ball mechanism. Once it was modified, it worked as expected in the microgravity environment.

KC-135 evaluations allow us to see the effects of weightlessness on human performance while performing tasks and gives assistance in identifying the crew's needs and concerns. This was shown during the workstation evaluations, when the crew desired additional hand holds so that they would avoid accidentally grabbing onto any protruding controls.

However, there are some limitations to performing experiments onboard the KC-135. Some examples of these are that there are a limited number of qualified subjects, short set up times for the experiments, can encounter unexpected hardware problems and extraneous plane movements such as air turbulence. In addition, it is not suitable to test the effects of extended microgravity exposure.

CONCLUSIONS

Experiments conducted onboard the KC-135 enable us to achieve real time experience in a microgravity environment while creating challenges in selecting human performance measures and they can best serve the function as being a precursor for shuttle experiments.

Microgravity (KC-135) evaluations were very useful to determine the effects of "weightlessness" on human performance, to identify crew needs, and to refine overall designs. Measuring human performance in simulated microgravity environments, such as the KC-135, will contribute to the efforts of optimizing the human - machine interfaces for future and existing space vehicles. It will also ensure safe and productive work environments for the crewmembers.

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